526 Rec'd PCT/PTO 05 OCT 2000

FORM PTO-1390 (Modified) (REV 10-95) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	031/01844 PCT
	U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 09/647776
INTERNATIONAL APPLICATION NO. **PCT/IL98/00172** — INTERNATIONAL FILING DATE **April 8, 1998**	PRIORITY DATE CLAIMED
TITLE OF INVENTION **SENSOR FOR BODY SOUNDS**	
APPLICANT(S) FOR DO/EO/US **Noam GAVRIELY; Maier FENSTER**	

OIPE OCT 0 5 2000 PATENT & TRADEMARK OFFICE

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210).
8. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 18 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
    A **SECOND** or **SUBSEQUENT** preliminary amendment.
16. ☐ A substitute specification.
17. ☐ A change of power of attorney and/or address letter.
18. ☐ Certificate of Mailing by Express Mail
19. ☒ Other items or information:

> 1. **Amendments to the claims of the International Application under PCT Article 34 are transmitted herewith as annexes to the IPER**
> 2. **A verified statement claiming small entity status is transmitted herewith**

PCTUS1/REV03

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U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR) 09/647776	INTERNATIONAL APPLICATION NO. PCT/IL98/00172	ATTORNEY'S DOCKET NUMBER 031/01844

20. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

	CALCULATIONS	PTO USE ONLY
☒ Search Report has been prepared by the EPO or JPO .... ~~$930.00~~ $840.00		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) $720.00		
☐ No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) $790.00		
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO $1,070.00		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $98.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	**$840.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	33 - 20 =	13	x $18.00	**$234.00**	
Independent claims	3 - 3 =	0	x $80.00	**$0.00**	
Multiple Dependent Claims **(check if applicable).**			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$1,074.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable).**			☒	**$537.00**	
SUBTOTAL =				**$537.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
TOTAL NATIONAL FEE =				**$537.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).**			☐	**$0.00**	
TOTAL FEES ENCLOSED =				**$537.00**	
				Amount to be: refunded	$
				charged	$

☐ A check in the amount of to cover the above fees is enclosed.

☒ Please charge my Deposit Account No. **03-3419** in the amount of **$537.00** to cover the above fees. A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **03-3419** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Roy N. Envall, Jr.
c/o Anthony Castorina
2001 Jefferson Davis Highway, Suite 207
Arlington, VA 22202

Tel: (703) 415-1581

Paul Fenster
SIGNATURE

Paul FENSTER
NAME

33,877
REGISTRATION NUMBER

October 3, 2000
DATE

031/01844 A01

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	N. GAVRIELY, et al.
Serial Number:	Not Yet Assigned
Filed:	8 April 1998 as PCT/IL98/00172 and Herewith as US National Stage
For:	Sensor for Body Sounds
Art Unit:	Not Yet Assigned
Examiner:	Not Yet Assigned

Honorable Commissioner of Patents and Trademarks
Washington DC 20231

PRELIMINARY AMENDMENT

Sir:

Further to the concurrent filing of the U.S. national stage of PCT/IL98/00172 kindly amend the application as follows prior to examination:

IN THE SPECIFICATION

Kindly add the following, on page 1, immediately after the title:

--RELATED APPLICATIONS

The present application is a US national application of PCT/IL98/00172, filed 8 April 1998.--

IN THE CLAIMS

Claim 3, line 1, change "any of the preceding claims" to --claim 1--.

Claim 5, line 1, change "any of the preceding claims" to --claim 1--.

Claim 9, line 1, delete "or claim 8".

Claim 10, line 1, change "any of claims 7-9" to --claim 7--.

Claim 11, line 1, change "any of the preceding claims" to --claim 7--.

Claim 14, line 1, change "any of claims 11-13" to --claim 11--.

Claim 18, line 1, change "any of claims 5-17" to --claim 7--.

Claim 19, line 1, change "any of claims 5-18" to --claim 7--.

Claim 20, line 1, change "any of claims 5-18" to --claim 7--.

Claim 21, line 1, change "any of claims 5-20" to --claim 7--.

Claim 24, line 1, change "any of claims 3-23" to --claim 7--.

Claim 25, line 3, change "any of the preceding claims" to --claim 7--.

Claim 28, line 1, delete "or claim 27".

Kindly add the following new claims:

--32. A device according to claim 1 wherein the cancellation circuitry comprises an equalizer which adjusts the amplitude of at least one of the primary sensor and secondary sensor signals to reduce the component in the output signal that is responsive to the airborne sound.

33. A method of detecting sounds generated in a body in the presence of airborne sounds comprising:

placing a device according to claim 1 against the body, such that the first sensor contacts the body; and

producing an output signal.--

REMARKS

The present application is a US national application of PCT/IL98/00172. The present amendments, based on the claims attached to the IPER, have been made to place the application in proper US form. Claims 32 and 33 have been added.

Applicants note that the claims were indicated as meeting the criteria of PCT Article 33(2)-33(4) in the IPER issued by the European Patent Office (acting as IPEA).

An action on the merits is respectfully awaited.

Respectfully submitted,
N. GAVRIELY et al.

Paul Fenster

Paul FENSTER
Reg. No. 33,877

October 3, 2000

Roy N. Envall, Jr.
c/o Anthony Castorina
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VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) AND 1.27 (c)) - SMALL BUSINESS CONCERN	Docket No. 031/01844

Serial No.	Filing Date	Patent No.	Issue Date
US Nat'l of PCT/IL98/00172	HEREWITH		

Applicant/
Patentee: **Noam GAVRIELY; Maier FENSTER**

Invention: **SENSOR FOR BODY SOUNDS**

I hereby declare that I am:

- ☐ the owner of the small business concern identified below:
- ☒ an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF CONCERN: **Karmel Medical Acoustic Technologies Ltd.**
ADDRESS OF CONCERN: **P.O. Box 55, Yokneam - Illit 20692, Israel**

I hereby declare that the above-identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under Section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the above identified invention described in:

- ☒ the specification filed herewith with title as listed above.
- ☐ the application identified above.
- ☐ the patent identified above.

If the rights held by the above-identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed on the next page and no rights to the invention are held by any person, other than the inventor, who could not qualify as an independent inventor under 37 CFR 1.9(c) or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

☒ no such person, concern or organization exists.
☐ each such person, concern or organization is listed below.

FULL NAME ______
ADDRESS ______
☐ Individual ☐ Small Business Concern ☐ Nonprofit Organization

FULL NAME ______
ADDRESS ______
☐ Individual ☐ Small Business Concern ☐ Nonprofit Organization

FULL NAME ______
ADDRESS ______
☐ Individual ☐ Small Business Concern ☐ Nonprofit Organization

FULL NAME ______
ADDRESS ______
☐ Individual ☐ Small Business Concern ☐ Nonprofit Organization

Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING: **Yitzhak KOHAVI**
TITLE OF PERSON SIGNING
OTHER THAN OWNER: **President & COO**
ADDRESS OF PERSON SIGNING: **22 Naama Street, Haifa 34670, Israel**

SIGNATURE: ______ DATE: 10/2/2000

SENSOR FOR BODY SOUNDS

FIELD OF THE INVENTION

The present invention relates generally to sensors, and specifically to systems suitable for use in body sounds detection and analysis.

BACKGROUND OF THE INVENTION

The art of listening to body sounds, or auscultation, has been used by physicians for thousands of years, for diagnosing various diseases.

Auscultation was initially performed by placing the physician's ear directly on the skin of the patient. At the beginning of the 19th century, R.T. Laennec introduced a tool, the stethoscope, for transmitting of body sounds to the ear.

Currently used stethoscopes include a "chest piece" brought into contact with the patient's skin, and two flexible tubes, terminating in the physician's ears.

The use of various sensors which transform the shocks and vibrations produced by body sounds into electrical voltages is well known in the art. Various types of transducers have been used in implementing body sound sensors, including both air coupled and contact microphones or accelerometers.

Swedish patent 8702647-2 to Hök describes a contact microphone in which the vibrations of the body surface induce deformations of a piezoelectric transducer. Contact sensors using such a piezoelectric element are sensitive to electromagnetic noise caused by nearby AC power lines, by static electricity discharges or by nearby electric devices.

In general, sound detecting devices are made to reject shocks and vibrations induced by structure-borne sounds and detect induced by airborne sounds. Devices also exist which are made immune to airborne isotropic sound.

A sensor which detects only relative vibrations while rejecting non relative ones is described in US patent 5,456,116 to Lew. The sensor uses a piezoelectric transducer and a mechanical structure to differentiate the vibrations to be detected from those to be rejected.

US patent 5,335,282 to Cardas, describes a microphone for air conducted sound in which two or more transducers perform simultaneous measurements. Transducer outputs are summed such as to make this device substantially immune to shock and vibration.

Driving a transducer from opposite directions by airborne sounds has also been used to cancel noise. An example of such a device is an aircraft radio noise canceling microphone in which a transducer, driven from opposite directions substantially cancels airborne noise while not affecting directional sound.

SUMMARY OF THE INVENTION

It is an object of some of preferred embodiments of the invention to provide a sensor for detecting vibrations conducted to the sensor through a body, while rejecting airborne sounds such as speech. Preferably, vibrations to be detected are those caused by body sounds.

In accordance with a preferred embodiment of the invention, the sensor performs at least two measurements, where the relative polarity of the body sounds and the airborne sounds is different in the two measurements.

In accordance with a preferred embodiment of the invention, the measurements are performed by transducers. Preferably, the transducers are piezoelectric elements.

In accordance with a preferred embodiment of the invention, the piezoelectric elements are mechanically connected to membranes which vibrate in response to body and airborne sounds. Preferably, one of the membranes is in contact with the body.

Further, in accordance with a preferred embodiment of the invention, the membranes, preferably metallic, are mechanically coupled to each other, preferably by a gas or liquid.

In some preferred embodiments of the present invention, the output of transducers are combined, preferably by a differential amplifier, so that the airborne sounds are at least partly canceled.

In some preferred embodiments of the present invention, airborne sound reaches one of the membranes directly from surroundings, and reaches the other membrane through the body.

In some preferred embodiments of the present invention, the amplitude response to airborne sounds of the membrane receiving such sounds directly is adjusted so as to be as close as possible to the amplitude response to airborne sounds of the membrane in contact with the body.

In some preferred embodiments of the present invention, the adjustment of the amplitude response is made by mechanically loading the membrane facing the air, preferably by coating the membrane with a thin layer of a substance.

In some other preferred embodiments of the present invention, the amplitude response adjustment is made by an electrical trimmer and/or by utilizing weighted combination of the amplitude response of the two membranes when combining the outputs of the elements.

In some preferred embodiments of the present invention, the amplitude response adjustment is automatically performed to calibrate the sensor.

There is thus provided, in accordance with a preferred embodiment of the invention, a device for detecting sounds generated within a body comprising:

a primary sensor placed on the body which receives first sound vibrations caused by the sounds generated within the body and second sound vibrations caused by airborne sound and which generates a primary electrical sensor signal in response thereto comprised of first and second portions, in a first ratio, responsive to said first and second sound vibrations respectively; and

airborne sound cancellation circuitry which receives the first signal and produces an output signal comprised of first and second portions, in a second ratio higher than said first ratio, responsive to said first and second sound vibrations respectively.

Preferably, the second portion of said primary sensor signal is responsive to airborne sound which travels to said first sensor via said body.

In a preferred embodiment of the inventor the device includes a secondary sensor which receives airborne sound and produces a secondary sensor signal wherein said airborne sound cancellation circuitry utilizes said secondary sensor signal to produce said output signal. Preferably, the secondary sensor signal comprises first and second portions responsive to said sounds generated within the body and said airborne sounds.

In a preferred embodiment of the invention the cancellation circuitry combines a signal derived from the secondary sensor signal with a signal derived from the primary sensor signal in forming said output signal.

In a preferred embodiment of the invention, the cancellation circuitry comprises an equalizer which adjusts the amplitude of at least one of the primary sensor and secondary sensor signals to increase said second ratio. Preferably, equalizer provides a frequency dependent adjustment to at least one of the primary and secondary signals. Alternatively, the equalizer provides a frequency independent adjustment to at least one of the primary and secondary signals.

In a preferred embodiment of the invention, the device includes equalizer adjustment circuitry which, in a calibration mode adjusts the equalizer to reduce the second portion of the output signal in response to an airborne sound.

In a preferred embodiment of the invention, the device a sound generator which, during the calibration mode, produces an airborne sound and wherein said adjustment circuitry adjusts said equalizer circuitry to reduce the response of the device to a minimum value. In a preferred embodiment of the invention the thus produced airborne sound is essentially a single frequency sound. Alternatively, the sound generator produces airborne sound at a plurality of frequencies in said calibration mode.

In a preferred embodiment of the invention, the primary sensor comprises a primary membrane and a primary transducer and the primary transducer produces said primary sensor output responsive to deformations of the primary membrane. Preferably the primary transducer is a piezoelectric element.

Preferably, the secondary sensor comprises a secondary membrane and a secondary transducer and the secondary transducer produces said secondary sensor output responsive to deformations of the secondary membrane. Preferably, the secondary transducer is a piezoelectric element.

Preferably, the secondary membrane is displaced from the first membrane.

In a preferred embodiment of the invention the secondary membrane is coated with a material to reduce the response of the secondary sensor to airborne signals.

In a preferred embodiment of the invention the secondary member is coated with a membrane having a response similar to that of the human skin.

In a preferred embodiment of the invention, the secondary membrane is of a different thickness than the first membrane to reduce the response of the secondary sensor to airborne signals.

In a preferred embodiment of the invention, the first and second sensors are mechanically or acoustically coupled such that vibrations of said primary membrane cause vibrations of the secondary membrane. Preferably, the coupling comprises a closed volume of gas or liquid and the primary and secondary membranes each form portions of an enclosure of the volume.

Preferably, the membrane is a metallic membrane.

There is further provided, in accordance with a preferred embodiment of the invention a device for measurement of sounds conducted from the interior of the body to its surface in the presence of airborne sounds conducted through the body comprising:

a primary sensor comprises a primary membrane and a primary transducer, wherein the primary transducer produces a primary sensor output signal responsive to deformations of the primary membrane;

a secondary sensor comprising a secondary membrane and a secondary transducer, wherein the secondary transducer produces a secondary sensor output signal responsive to deformations of the secondary membrane; and

airborne sound cancellation circuitry which combines a signal derived from said secondary sensor output signal from a said primary output signal to produce an output signal having a reduced component responsive to the airborne sound.

Preferably, the cancellation circuitry comprises an equalizer which adjusts the amplitude of at least one of the primary sensor and secondary sensor signals to reduce the component responsive to the airborne sound. Preferably, the equalizer provides a frequency dependent adjustment to at least one of the primary and secondary signals. Alternatively the equalizer provides a frequency independent adjustment to at least one of the primary and secondary signals.

In a preferred embodiment of the invention, the device includes equalizer adjustment circuitry which, in a calibration mode adjusts the equalizer to reduce the second portion of the output signal in response to an airborne sound. Preferably the device includes a sound generator which, during the calibration mode, produces an airborne sound and wherein said adjustment circuitry adjusts said equalizer circuitry to reduce the response of the device to a minimum value. In a preferred embodiment of the invention, the thus produced airborne sound is essentially a single frequency sound. Alternatively, the sound generator produces airborne sound at a plurality of frequencies in said calibration mode.

There is further provided, in accordance with a preferred embodiment of the invention a method of detecting sounds generated in a body in the presence of airborne sounds comprising:

placing a device according to preferred embodiments of the invention against the body; and

producing an output signal.

There is further provided, in accordance with a preferred embodiment of the invention, a method of reducing the effect of airborne sound on a measurement of sounds produced in a body and measured at the surface thereof comprising:

providing a signal responsive to sound produced in the body and measured at the surface of the body and contaminated by a signal responsive to said airborne sounds;

providing a second signal having at least a component responsive to said airborne sounds; and

processing the first signal utilizing the second signal to produce an output signal having a reduced the relative amplitude of the signal responsive to airborne sounds..

In a preferred embodiment of the invention, providing a second signal comprises providing a second signal having a component responsive to sound produced in the body wherein the relative polarity of the signals responsive to the airborne and body produced sound is reversed for the second signal as compared to the first signal.

In a preferred embodiment of the invention, the method includes adjusting at least one of the first and second signals to further reduce the relative amplitude of the signal responsive to the airborne sounds.

Preferably, the adjustment is determined during a calibration stage comprising:

placing a device providing the first and second signals on the body in a position at which such measurement is to be made;

providing an airborne audio signal;

adjusting at least one of the first and second signals to minimize the response of the output signal to said provided airborne signal; and

utilizing said adjustment when measuring body sounds.

In a preferred embodiment of the invention, the adjustment is frequency insensitive. Alternatively, the adjustment varies with frequency.

The present invention will be more clearly understood from the following description of the preferred embodiments of the invention taken together with the following drawings in which:

BRIEF DESCRIPTION OF THE DRAWING

Fig. **1** schematically shows the logic of operation and a cross-sectional view of the construction of a sensor, in accordance with a preferred embodiment of the present invention and

Fig. **2** schematically shows a cross-sectional view of the construction of a sensor in accordance with an alternative preferred embodiment of the invention and a preferred method of mounting the sensor.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. **1** schematically depicts the logic of a sensor **6** in accordance with a preferred embodiment of the present invention. Sensor **6** comprises a pair of membranes **10** and **12**, a pair of transducers **14** and **16**, a combiner **18** and a housing **42** to which the membranes **10** and **12** are attached. A gas or liquid **22** fills enclosure **20** and mechanically couples membranes **10** and **12**. Use of different gases or liquids **22** will result in different mechanical coupling of membranes **10** and **12**.

When vibrating, membranes **10** and **12** transfer their vibrational energy to transducers **14** and **16** to which they are conductively glued. Transducers **14** and **16** transform this energy into another form, preferably electrical energy. Outputs **30** and **32** of transducers **14** and **16** are combined by combiner **18** and extracted from sensor **6** as a final output **40**.

Membranes and surfaces vibrate whenever sound or vibrations reach them, as for example surfaces **24** of a body **26** under the influence of body sounds **28** created inside body **26**. To detect vibrations induced by body sounds **28**, the surface of membrane **10** is brought into contact with surface **24**. For reasons of clarity the contact of membrane **10** and surface **24** is not shown in Fig. **1**, however, they are shown in contact in Fig. **2** which is shows an alternative preferred embodiment of the invention. Vibrations induced by body sounds **28** which reach surface **24** (arrow **III**) are transmitted to membrane **10** by physical contact and then, through coupling medium **22**, to membrane **12** arrow (arrow **IV**). Airborne sounds **34** such as speech, are transmitted directly to membrane **12** (arrow **V**) and through body **26** (arrows **VI**, **VII**) to membrane **10**. The relative polarity of body and airborne vibrations received by membrane **10** (arrows **III** and **VII**) is different from the relative polarity of those vibrations received by membrane **12** (arrows **IV** and **V**). Combiner **18** combines outputs **30** and **32** so as to subtract the portion of the output generated by airborne sound **34** which reaches membranes **10**, **12**, and to add the portion of the output generated by body sounds **28**. In a preferred embodiment of the invention, the amplitude of vibrations induced by airborne sound **34** in membrane **12** is controlled, as to match it as closely as possible to the amplitude of vibrations induced by airborne sound **34** in membrane **10** so that the amplitude response of the two transducers to airborne sounds is substantially the same. Airborne sound which may reach membrane **10** through the coupling medium does not affect the proper operation of a sensor built in accordance with this embodiment, because the amplitude of vibrations induced by airborne sound **34** in membrane **12** is matched as closely as possible to the algebraic sum of the amplitudes of airborne sound received at membrane **10** through the body and through coupling medium. Additionally or alternatively, the efficiency of coupling medium **22**, does not affect the proper operation of a sensor built in accordance with this embodiment, because, even if no body sound **28** can reach membrane **12**, cancellation of airborne sound in accordance with the above, will still be performed by controlling the amplitude of vibrations induced by airborne sound in membrane **12**, with no dependence on relative polarity of sounds detected by membranes **10** and **12**.

In a preferred embodiment of the invention, the amplitude of vibrations induced by airborne sound in membranes **10** and **12** is obtained by contacting membrane **12** with substance **36** which alters its amplitude response, preferably matching its response to that of the human skin. Alternatively or additionally, the response is altered by putting some distributed weights, (not shown), on the membrane. Alternatively or additionally, airborne sound **34** which reaches membranes **10**, **12** in different directions, is electronically canceled by

weighted combination of outputs **30** and **32**. In a preferred embodiment of the present invention, algebraic addition of outputs **30** and **32** is performed in combiner **18** after the amplitude of output **32** is multiplied by a factor which matches it as closely as possible to the amplitude of part of output **30** related to airborne sound. Alternatively, the amplitude of output **32** is controlled by a trimmer **46** before it is combined with output **30**. It should be noted that to the extent that the response is matched mechanically, the system becomes relatively immune from electromagnetic interference.

Membranes **10** and **12**, preferably are thin metallic sheets made of stainless steel, preferably between 200 and 250 microns thick. The membranes are preferably conductively glued to transducers **14** and **16** and, at contact points **48**, to a preferably conductive sensor housing **42**. Transducers **14** and **16** are preferably piezoelectric crystals (PZT) although other transducers such as optical transducers may be used. Inner faces **52** and **54**, of PZTs **14** and **16** are respectively conductively connected to output wires **30A** and **32A**, while sensor housing **42** is grounded through wire **32B** at contact point **50**. Thus, the outer faces of transducers **14** and **16** are also grounded. Vibrations of membranes **10** and **12** induced by airborne sounds **34** in the directions of arrows **V** and **VII**, and by body sounds **28** in the direction of arrow **III** and **IV**, cause mechanical deformations on both PZT's which generate voltage difference between sensor housing **42**, and PZT's inner faces **54**, **52**. These voltage differences are of different polarity when related to airborne sounds, and of same polarity when related to body sounds. Electrical signals caused by the deformation of the PZTs are conducted through shielded, **38**, active wires **30A**, **32A** to combiner **18** which is preferably a differential amplifier.

Utilizing the above configuration, the part of outputs **30** and **32** related to airborne sounds **34** are canceled by differential amplifier **18**, while the part related to body sounds **28** is extracted as final output **40**.

In a preferred embodiment of the invention, the output of transducer **16** is additionally fed to a second operational amplifier (not shown), for use by breath sound equipment as an ambient noise detector.

As indicated above, in some of the preferred embodiments, the amplitude of vibrations induced by airborne sounds **34** in membrane **12** is matched to that induced in membrane **10** by contacting it with a substance **36**, preferably by coating or pasting a thin layer on membrane **12**. It has been found that a closed cell foam tape such as 3M type 1772 Foam Medical Tape with a thickness of 1.2 mm is suitable.

Alternatively or additionally, in some preferred embodiments, electronic adjustment of the amplitude of signals **30** and **32** is used. In these embodiments, trimmer **46** is adjusted to match the amplitude of the outputs of transducers **14** and **16** to airborne sounds.

In a preferred embodiment of the invention, the transducer **16** may be calibrated, in situ, to provide optimum cancellation of airborne sounds. In this embodiment, after placement of the sensor on the body, airborne sound is generated. This sound may be speech or other sound. Trimmer **46** or the relative gain of the channels of combiner **18** are varied to provide minimum signal, at **40**, from such sounds.

In a further preferred embodiment of the invention, alternative or additional to trimmer **46**, a servo controlled equalizer is used to equalize, at predetermined frequencies of the audio spectrum, the part of outputs **30** and **32** generated by airborne sounds. In this preferred embodiment of the invention airborne sound preferably at individual frequencies is generated, preferably corresponding to the center frequencies of bands of the equalizer. Circuitry receives the outputs generated in response to sound at the individual frequencies and changes the respective channel transmission of the equalizer until the output at **40** is minimized or eliminated.

Fig. **2** shows a sensor, in accordance with an alternative preferred embodiment of the invention, in which housing **42** is formed of a plastic material. For this embodiment membranes separate connection is preferably made to the outside surfaces of transducers **14** and **16**, preferably via membranes **10** and 12. In this case epoxy **48'** need not be conductive.

Fig. **2** also illustrates a preferred method of attaching the sensors of Figs. **1** or **2**. In this embodiment the sensor is surrounded by a sponge holding fixture **100** (which may be of the same material as forms the layer **36** of Fig. 1). The height of fixture **100** may be the same as or slightly less than that of housing **42**. Preferably fixture **42** is formed with a slit to allow for the easy removal of the sensor output cable shield **38** and the wires it contains. Fixture **100** is further formed with a sticky surface where it touches the skin of the subject such that it is securely, but removably attached thereto. In this preferred embodiment of the invention, a layer **102** of tape is preferably used to secure the fixture to the sensor. In a preferred embodiment of the invention, tape **102** is of the same material as described above with respect to the preferred embodiment of layer **36** of Fig. **1**. Thus, tape **102** provides the double function of securing the sensor and providing the desired loading of membrane **12**.

It is understood that the operation of a sensor in accordance with the logic and preferred embodiment of the present invention, is independent of the relative and absolute positioning of its constituent components. It is also understood that all the specific elements

described above are only representative of their functions, any other elements performing the same functions may be used in the construction of a sensor which acts in accordance with a preferred embodiment of the invention.

CLAIMS

1. A device for detecting sounds generated within a body comprising:

a primary sensor placed on the body which receives first sound vibrations caused by the sounds generated within the body and second sound vibrations caused by airborne sound and which generates a primary electrical sensor signal in response thereto comprised of first and second portions, in a first ratio, responsive to said first and second sound vibrations respectively; and

a secondary sensor mechanically or acoustically coupled to the first sensor internally in the device, which receives said first sound vibrations via said coupling and which receives said second vibrations directly from the air in addition to any such vibrations received via the coupling and which generates a secondary electrical sensor signal in response thereto comprised of first and second portions in a second ratio different from said first ratio; and

airborne sound cancellation circuitry which receives the first and second signals and produces an output signal comprised of first and second portions, in a third ratio higher than said first ratio in response to said first and second signals.

2. A device according to claim 1 wherein the second portion of said primary sensor signal is arranged such that it is responsive to airborne sound which travels to said primary sensor via said body.

3. A device according to any of the preceding claims wherein the primary sensor comprises a primary membrane and a primary transducer, wherein the primary transducer produces said primary sensor output responsive to deformations of the primary membrane.

4. A device according to claim 3 wherein the primary transducer is a piezoelectric element.

5. A device according to any of the preceding claims wherein the secondary sensor comprises a secondary membrane and a secondary transducer, wherein the secondary transducer produces said secondary sensor signal responsive to deformations of the secondary membrane.

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6. A device according to claim 5 wherein the secondary transducer is a piezoelectric element.

7. A device for measurement of sounds conducted from the interior of the body to its surface in the presence of airborne sounds conducted through the body comprising:

a primary sensor comprising a primary membrane and a primary transducer, wherein the primary transducer produces a primary sensor output signal responsive to deformations of the primary membrane;

a secondary sensor mechanically or acoustically coupled to the first transducer, internally to the device and comprising a secondary membrane and a secondary transducer, wherein the secondary transducer produces a secondary sensor output signal responsive to deformations of the secondary membrane; and

airborne sound cancellation circuitry which combines a signal derived from said secondary sensor output signal and a signal derived from said primary output signal to produce an output signal having a reduced component responsive to the airborne sound as compared with that present in said primary output signal.

8. A device according to claim 7, wherein when the device is placed on the body of a test subject,

the primary sensor receives first sound vibrations caused by the sounds generated within the body and second sound vibrations caused by airborne sound and wherein the primary sensor signal is comprised of first and second portions, in a first ratio, responsive to said first and second sound vibrations respectively;

the secondary sensor receives said first sound vibrations via said mechanical coupling and said second vibrations directly from the air in addition to any such vibrations received via the coupling such that said secondary electrical sensor signal is comprised of first and second portions in a second ratio different from said first ratio; and

the airborne sound cancellation circuitry produces an output signal comprised of first and second portions, in a third ratio higher than said first ratio in response to said first and second signals.

9. A device according to claim 7 or claim 8 wherein the primary sensor is a piezoelectric element.

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10. A device according to any of claims 7-9 wherein the secondary transducer is a piezoelectric element.

11. A device according to any of the preceding claims wherein the cancellation circuitry comprises an equalizer which adjusts the amplitude of at least one of the primary sensor and secondary sensor signals to reduce the component in the output signal that is responsive to the airborne sound.

12. A device according to claim 11 wherein said equalizer provides a frequency dependent adjustment to at least one of the primary and secondary signals.

13. A device according to claim 12 wherein said equalizer provides a frequency independent adjustment to at least one of the primary and secondary signals.

14. A device according to any of claims 11-13 and including equalizer adjustment circuitry which, in a calibration mode adjusts the equalizer to reduce the second portion of the output signal in response to an airborne sound.

15. A device according to claim 14 and including a sound generator which, during the calibration mode, produces an airborne sound and wherein said adjustment circuitry adjusts said equalizer circuitry to reduce the response of the device to a minimum value.

16. A device according to claim 15 wherein the thus produced airborne sound is essentially a single frequency sound.

17. A device according to claim 16 wherein the sound generator produces airborne sound at a plurality of frequencies in said calibration mode.

18. A device according to any of claims 5-17 wherein the secondary membrane is coated with a material to reduce the response of the secondary sensor to airborne signals.

19. A device according to any of claims 5-18 wherein the secondary membrane is coated with a film to have a response similar to that of the human skin.

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20. A device according to any of claims 5-18 wherein the secondary membrane is of a different thickness than the primary membrane to reduce the response of the secondary sensor to airborne signals.

21. A device according to any of claims 5-20 wherein the mechanical or acoustical coupling causes vibrations of the primary membrane to induce vibrations of the secondary membrane.

22. A device according to claim 21 wherein the coupling comprises a closed volume of gas and wherein the primary and secondary membranes each form portions of an enclosure of the volume.

23. A device according to claim 21 wherein the coupling comprises a closed volume of liquid and wherein the primary and secondary membranes each form portions of an enclosure of the volume.

24. A device according to any of claims 3-23 wherein the membrane is a metallic membrane.

25. A method of detecting sounds generated in a body in the presence of airborne sounds comprising:

placing a device according to any of the preceding claims against the body, such that the first sensor contacts the body; and

producing an output signal.

26. A method of reducing the effect of airborne sound on a measurement of sounds produced in a body and measured at the surface thereof comprising:

providing a signal responsive to sound produced in the body and measured at the surface of the body and contaminated by a signal responsive to said airborne sounds;

providing a second signal having at least a component responsive to said airborne sounds and a component responsive to said body sounds; and

processing the first signal utilizing the second signal to produce an output signal having a reduced the relative amplitude of the signal responsive to airborne sounds as compared with the first signal.

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27. A method according to claim 26 wherein providing a second signal comprises providing a second signal having a component responsive to sound produced in the body wherein the relative polarity of the signals responsive to the airborne and body produced sound is different for the second signal as compared to the first signal.

28. A method according to claim 26 or claim 27 and including adjusting at least one of the first and second signals to further reduce the relative amplitude of the signal responsive to the airborne sounds.

29. A method according to claim 28 wherein said adjustment is determined during a calibration stage comprising:

placing a device providing the first and second signals on the body in a position at which such measurement is to be made;

providing an airborne audio signal;

adjusting at least one of the first and second signals to minimize the response of the output signal to said provided airborne signal; and

utilizing said adjustment when measuring body sounds.

30. A method according to claim 29 wherein the adjustment is frequency insensitive.

31. A method according to claim 30 wherein the adjustment varies with frequency.

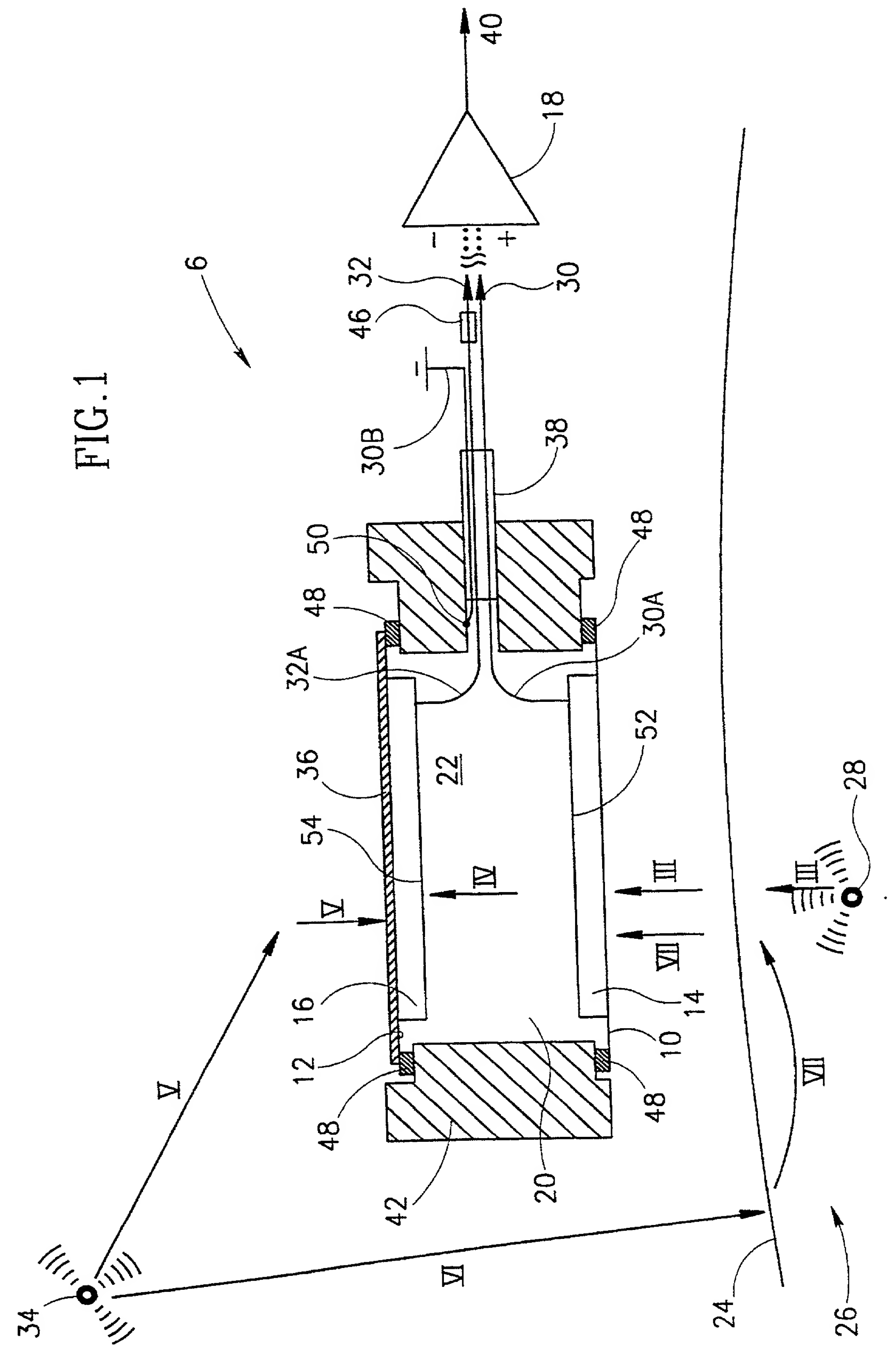
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FIG. 1

2/2

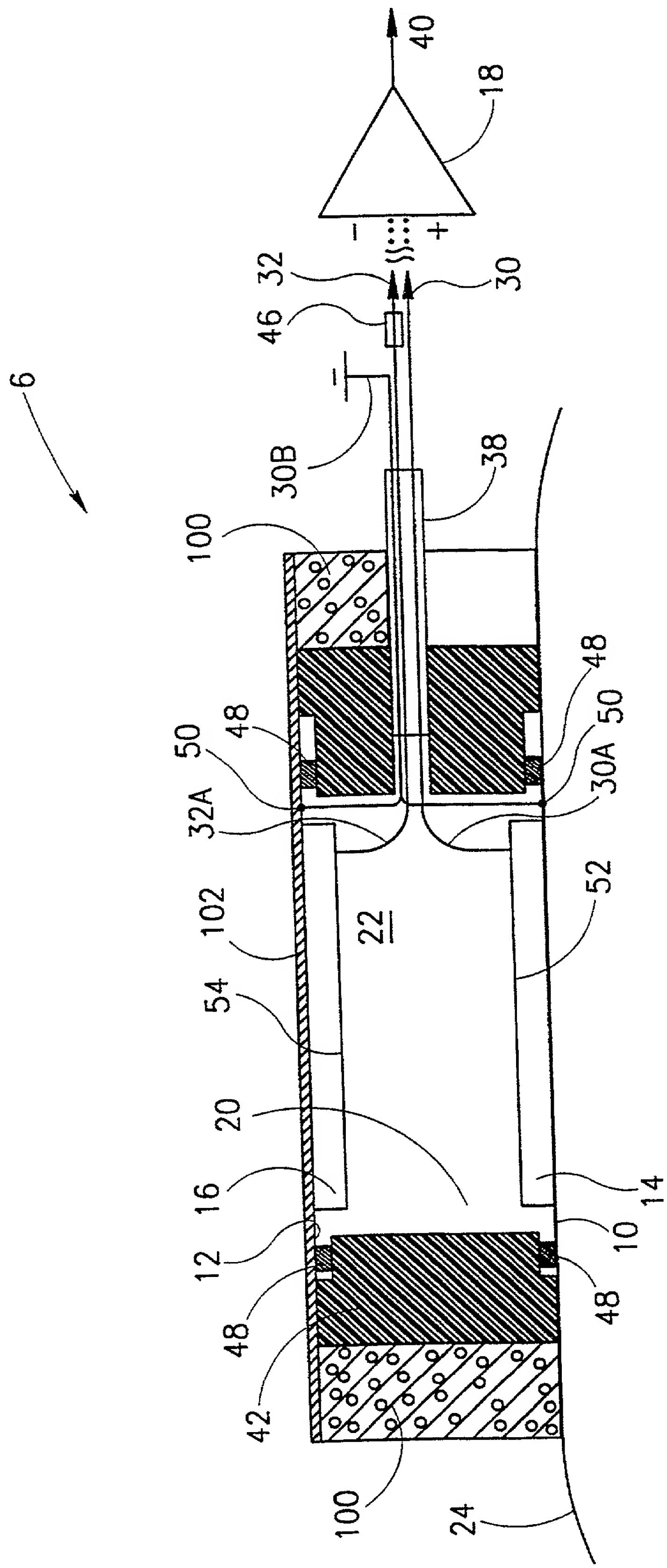
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FIG.2

Express Mail Label No.

Docket No.
031/01844

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

SENSOR FOR BODY SOUNDS

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on April 8, 1998 as United States Application No. or PCT International Application Number PCT/IL98/00172

and was amended on June 9, 2000

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)			Priority Not Claimed
(Number)	(Country)	(Day/Month/Year Filed)	☐
(Number)	(Country)	(Day/Month/Year Filed)	☐
(Number)	(Country)	(Day/Month/Year Filed)	☐

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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